2014 BSEE Domestic and International Standards Workshop

API 17TR11: Pressure Effects on Subsea Hardware During Pressure Testing in Deep Water (In Ballot)

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API 17TR12: Consideration of External Pressure in the Design and Pressure Rating of Subsea Equipment (In Working Group)

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API 17TR11: Pressure Effects on Subsea Hardware During Pressure Testing in Deep Water

Related Report: Formulating Guidance on Hydrotesting Deepwater Oil and Gas Pipelines – Stress Engineering Report to BSEE, Jan 31, 2013 and planned OTC Paper

The Main Challenges

- Lack of Common Definitions and understanding of Pressure Terms (MAOP, MSP, RWP, etc.) – Need to get regulators, pipeline-flowline and subsea hardware community on the same page.
- Simple design, without considerations of effect of internal and external hydrostatic fluid head, won’t work in deep water.
- Subsea hardware providers need to have a better understanding of magnitude of hydrostatic test pressure applied during subsea systems hydrostatic tests (this pressure may exceed RWP and approach or even exceed 1.5 RWP)

Definitions

- RWP – Rated Working Pressure of subsea hardware components (per API 6A & 17D specifications)
  - Typically applies to Valves, Flanges, Hubs, Other End Connectors, Fittings, etc
  - Interpreted by API to mean the “absolute pressure” of the fluid contained within the component (Ref: API 6A: “rated working pressure - maximum internal pressure that the equipment is designed to contain and/or control)
  - Introduction of new terms in API 17TR11: RWPA(Absolute) and RWPD (Differential)

- MAOP - Maximum Allowable Operating Pressure of the subsea flowline system (per pipeline code 30 CFR 250 and NTL 2009-G28)
- Po – External pressure
- Pd – Differential Design Pressure as per API RP 1111 (difference between internal and external pressure)
- MSP – Maximum Source Pressure (internal)

API 17TR11: Pressure Effects on Subsea Hardware During Pressure Testing in Deep Water

- Originated in industry workgroup started in 2011 to address effects of subsea systems hydrostatic test (via deepwater riser and flowline) on subsea hardware.
- Subsea flowlines are typically hydrostatically pressure tested to 1.25 X MAOP during pre-commissioning operations .
- For flowline systems connected with risers to a floating host, and no means to isolate the riser from the flowline, the test pressure is applied at top of riser – Thus, absolute pressure (PSIA) inside flowline on seabed is increased by the seawater head pressure (**inside pressure = 1.25 x MAOP + ambient seawater pressure Po**)
- BSEE does not allow for the concept of variable design pressure in a flowline/riser system (one cannot consider the density of produced fluid/gas in a production flowline/riser). Therefore, for production flowlines the MAOP is generally required to be constant throughout the system and equal to the Wellhead shut-in tubing pressure (WHSITP). See also NTL 2009-G28.
- Net result is that in most cases, subsea equipment will be exposed to an internal test pressure equal to 1.25 MAOP + Po. **<u>This internal test pressure may exceed the test pressure the subsea equipment was subjected to as part of onshore shop testing or other FAT.</u>**

API 17TR11: Pressure Effects on Subsea Hardware During Pressure Testing in Deep Water

- 5 Cases and Discussion and Cautionary Comments for Each Case

Case	Internal Subsea System Hydrotest Pressure	Rating
1	At or below 1.0*RWPA (and thus below 1.0*RWPD) of the hardware components	
2	Greater than 1.0*RWPA, but not above 1.0*RWPD	
3	Greater than 1.0*RWPD (thus greater than 1.0*RWPA), but not above 1.5*RWPA	
4	Greater than 1.5*RWPA, but not above 1.5*RWPD (or 1.25*MAOPD)	
5	Greater than 1.5*RWPD	

Example (Cases 3 and 4)

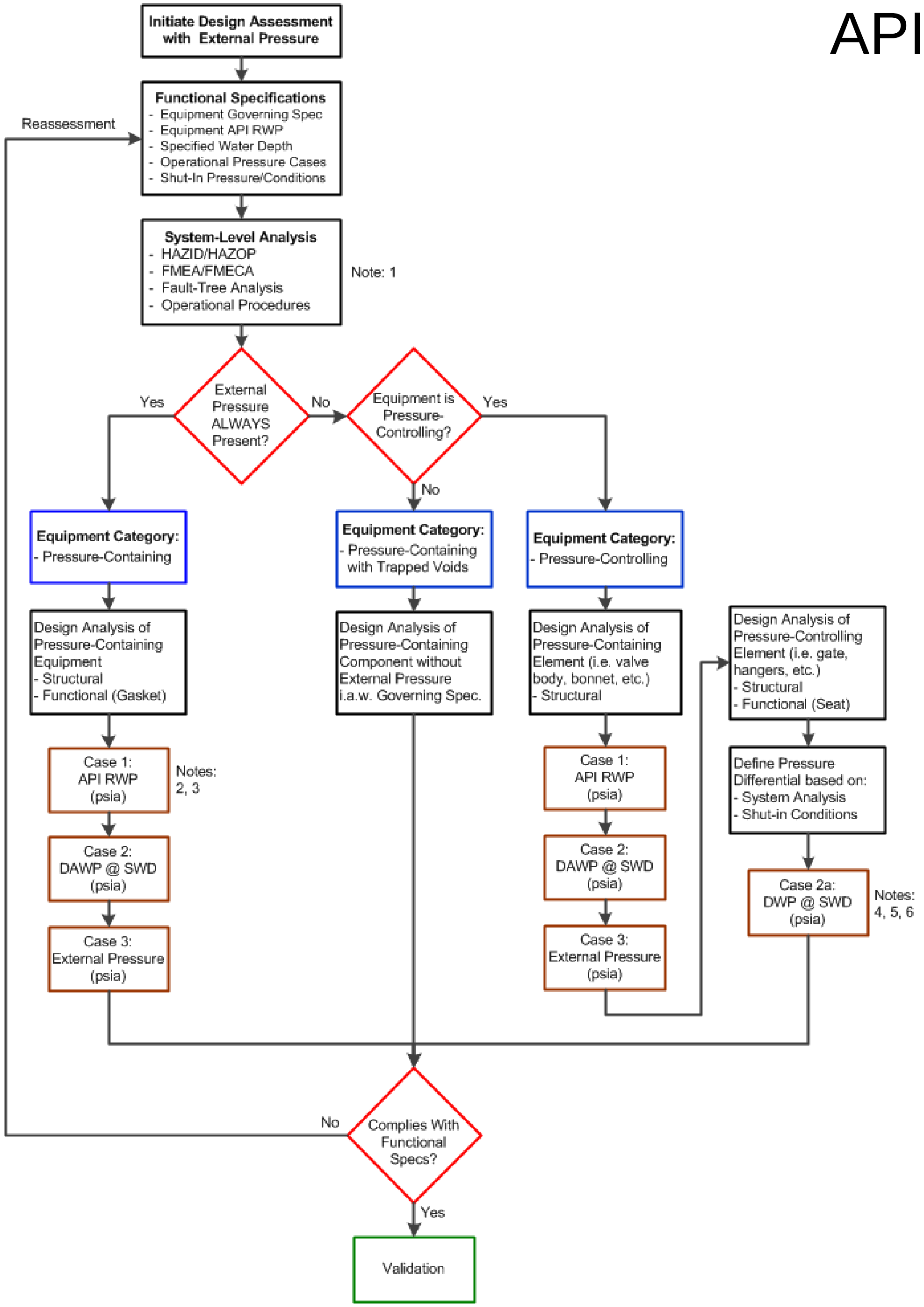
- Production Flowline MSP = 12,500 psi at manifold
- Water Depth = 9,000 ft (Po = 4,000 psi)
- Subsea equipment RWP = 15,000 psi
- MAOP as per 30 CFR 250 and NTL 2009-G28 = 12,500 psi
- Flowline connected with SCR to FPS
- Surface Minimum required test pressure = 1.25 MAOP = 15,625 psi
- Fabrication Yard Internal Test Pressure likely to be 15,625 psi
- Internal Test Pressure at Subsea Manifold = 15,625 + 4,000 = 19,625 psi = 1.30 x RWP: > 1.25 RWP but less than 1.5 RWP

  Is this OK?
- Same situation but MAOP = 14,500 psi.
- Internal Test Pressure at Manifold is now 22,125 psi = 1.48 RWP

  Is this OK?

API 17TR12: Consideration of External Pressure in the Design and Pressure Rating of Subsea Equipment

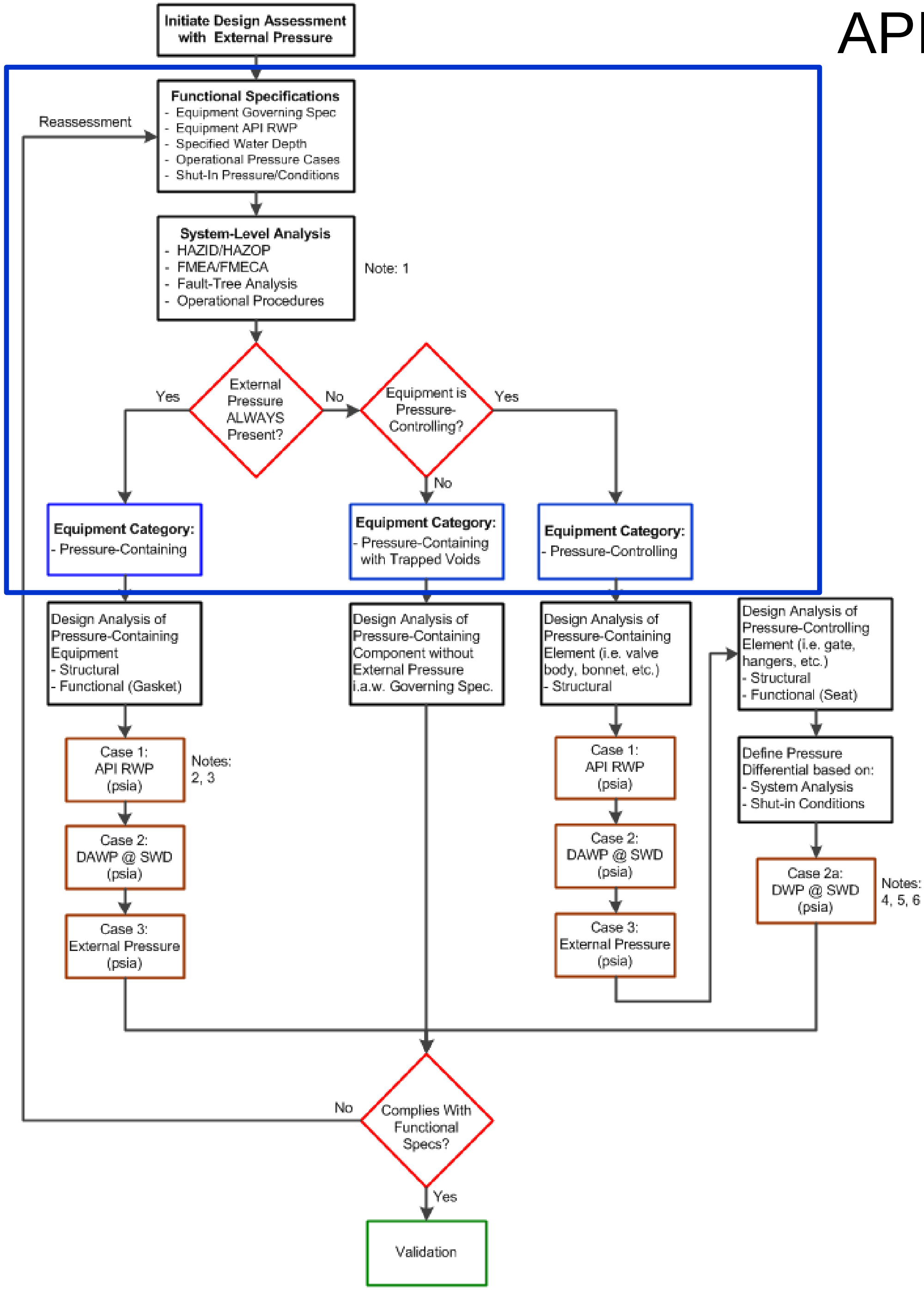
API 17TR12 Design Assessment Flow Chart



Notes (to flow chart):

1. To identify equipment / component / sub-component category due to presence of external pressure:
    a) pressure-containing;
    b) pressure-containing with trapped voids; or
    c) pressure-controlling.
2. DAWP: Depth Adjusted Working Pressure (psia)
3. SWD: Specified Water Depth (ft)
4. DWP: Differential Working Pressure (psig)
5. DWP = Max Upstream Pressure – Min. Downstream Pressure, on the pressure-controlling element, where the “Max. Upstream Pressure” can be the calculated DAWP
6. DWP $\leq$ API RWP

API 17TR12 Design Assessment Flow Chart



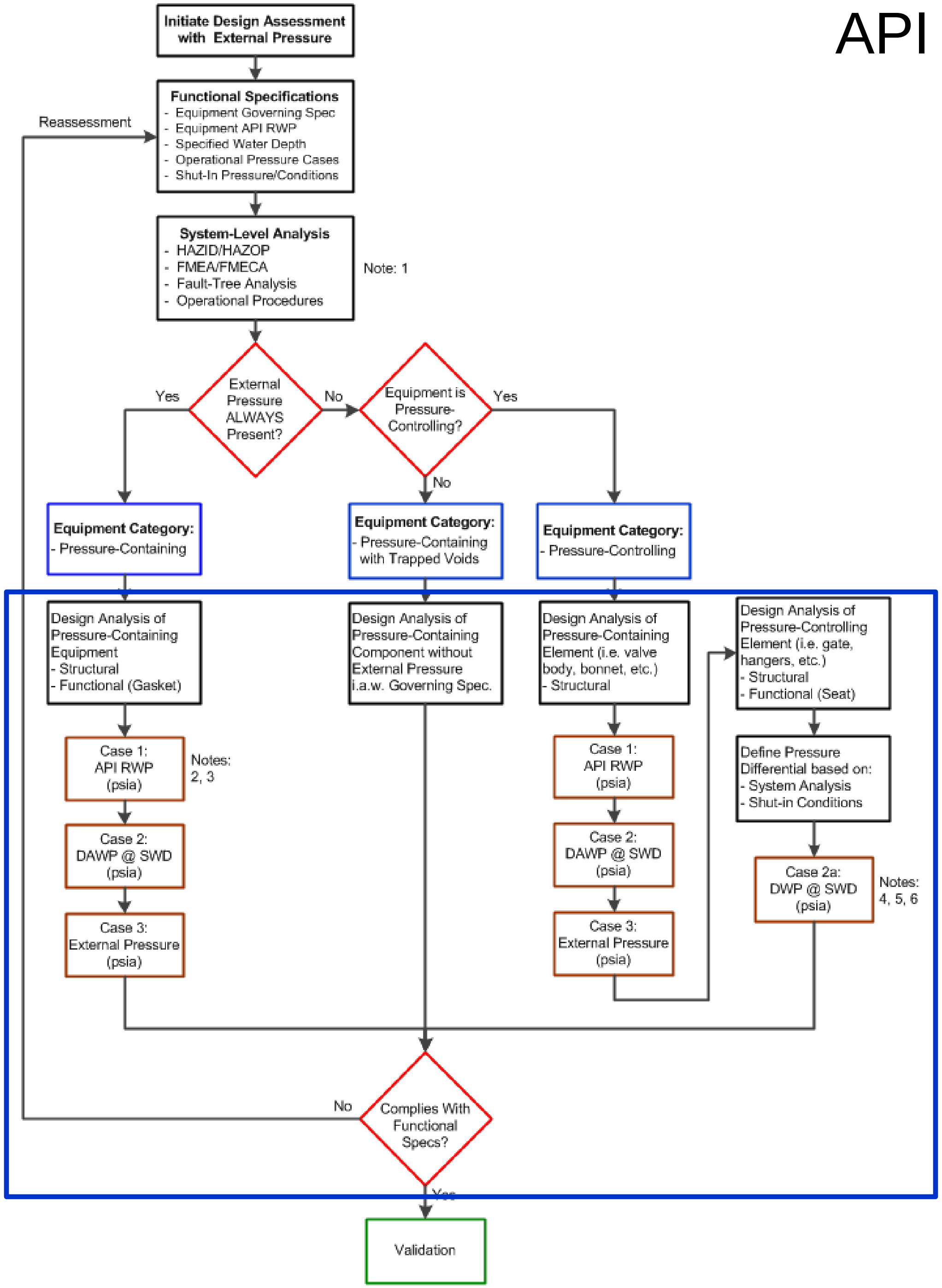
- Thorough understanding of system/ equipment operational and functional characteristics
- Perform hazard identifications / risk assessment
- Identify equipment category:

  a) pressure-containing;

  b) pressure-containing with trapped voids;

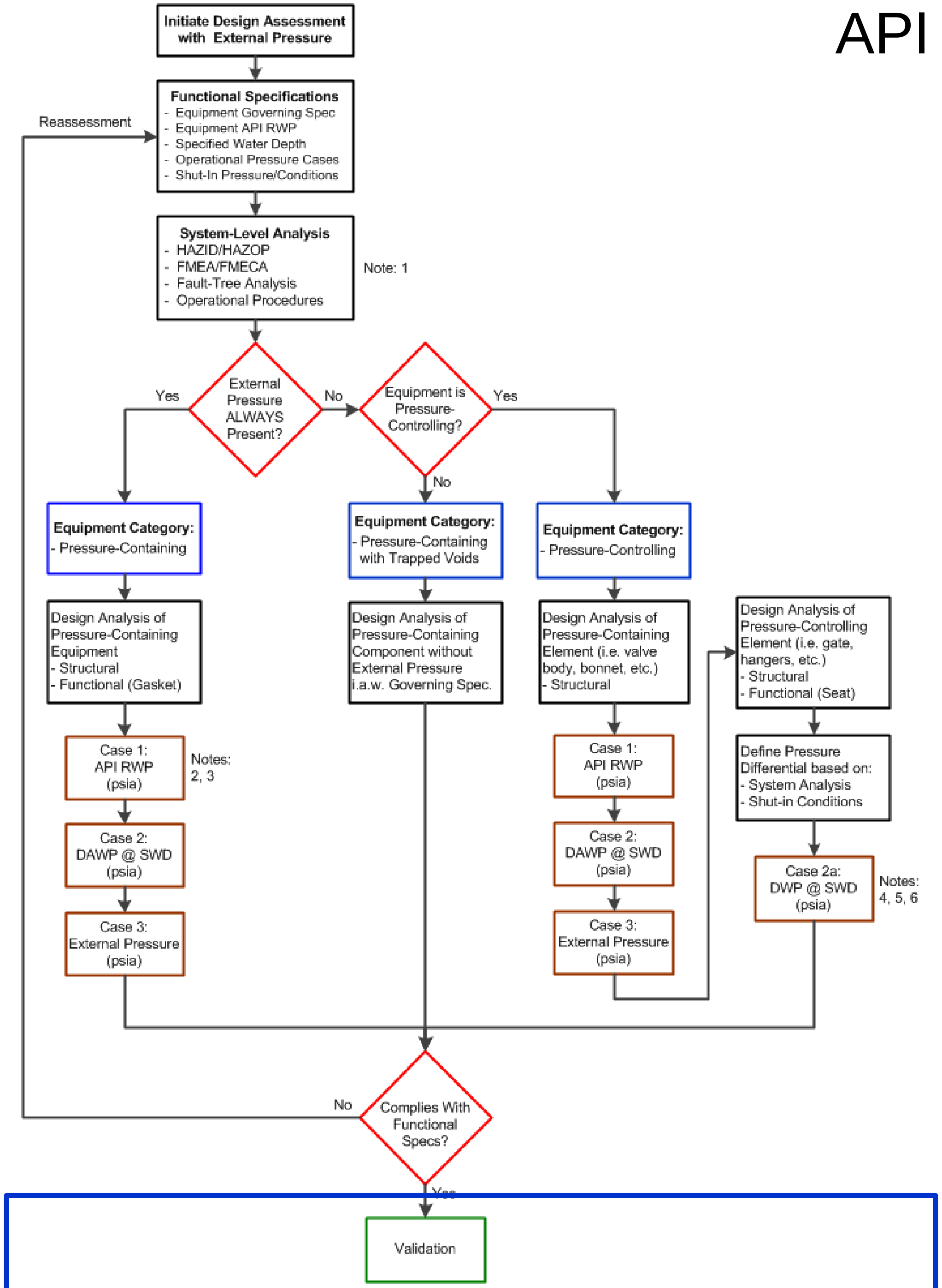
  c) pressure-controlling.

API 17TR12 Design Assessment Flow Chart



- Finite element analysis (FEA) of Case 1 - 3
- von Mises Equivalent (VME) stress should be used as it is the more accurate predictor of stress states
- Additional verifications for protection against:
  - Local failure / Localized stress concentrations
  - Ratcheting effects
- FEA results (stresses) shall comply with the applicable governing design specifications

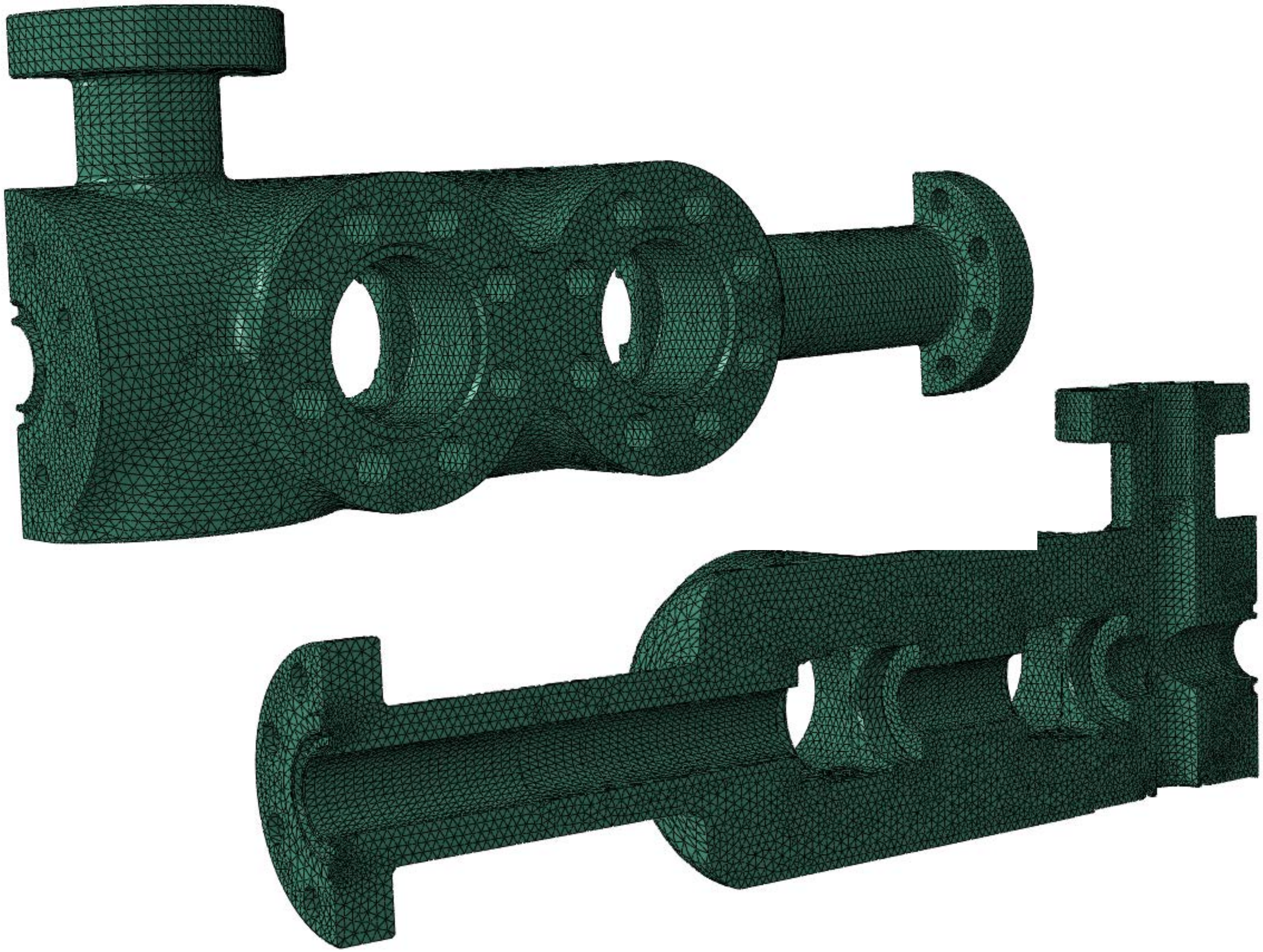
API 17TR12 Design Assessment Flow Chart



- Test in hyperbaric chamber or simulate external pressure with test fixtures
- For larger components, where hyperbaric testing is not practical, validation of FEA is allowed through ASME V&V 10-2006, Guide for Verification and Validation in Computational Solid Mechanics
- Factory Acceptance Testing (FAT) in accordance with governing product specifications

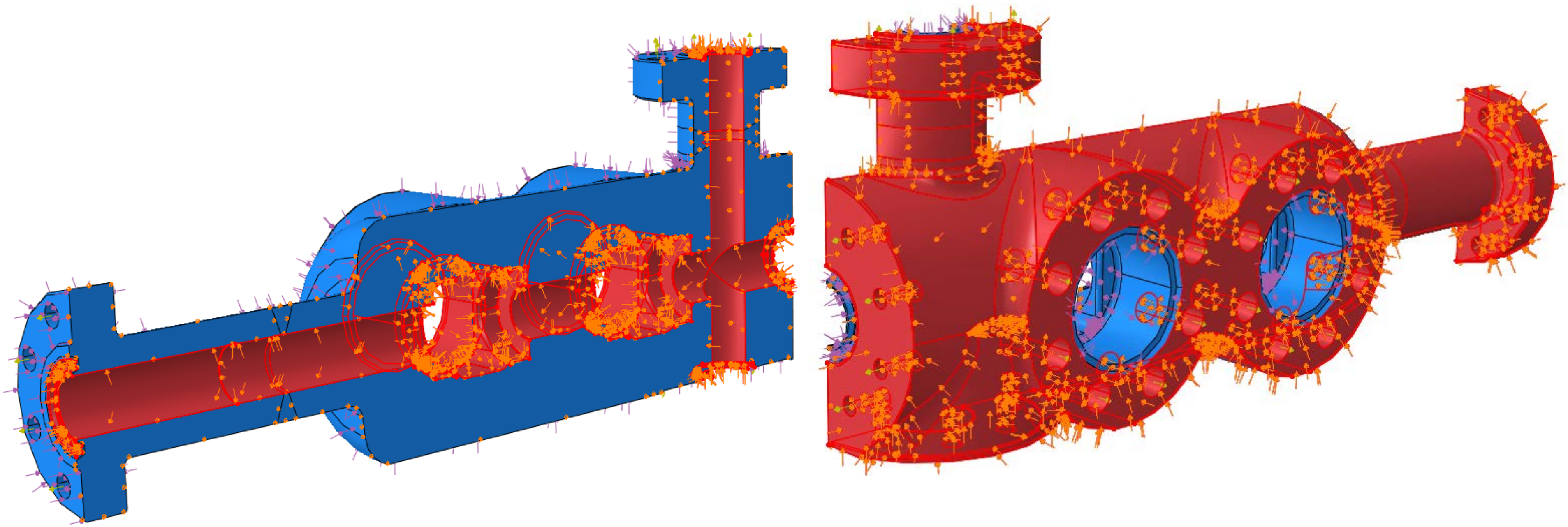
API 17TR12 – FEA Example

Mesh Density



Total number of nodes: 446,850; Total number of elements: 304,200 quadratic tetrahedral elements of type C3D10

Loads & BC's



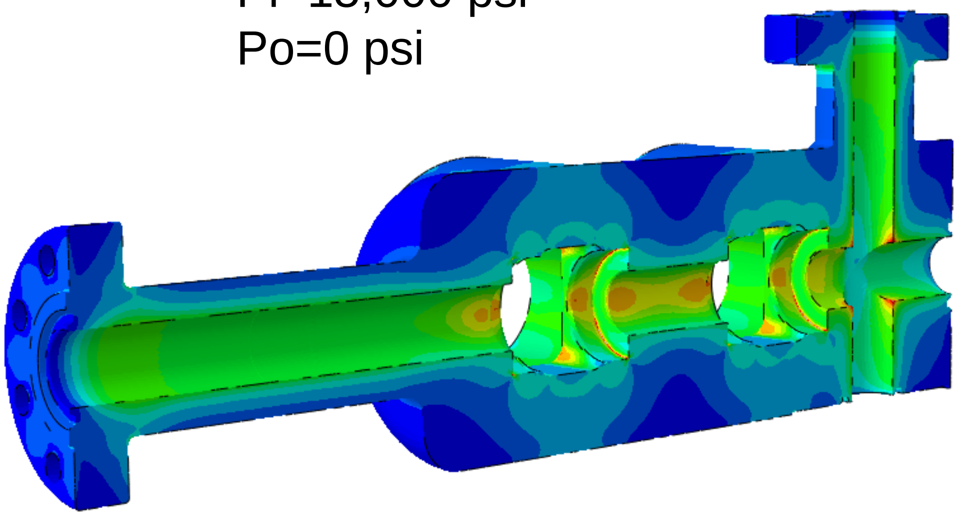
LC1:
Pi=15,000 psi
Po=0 psi

LC3:
Pi=18,000 psi
Po=3,000 psi

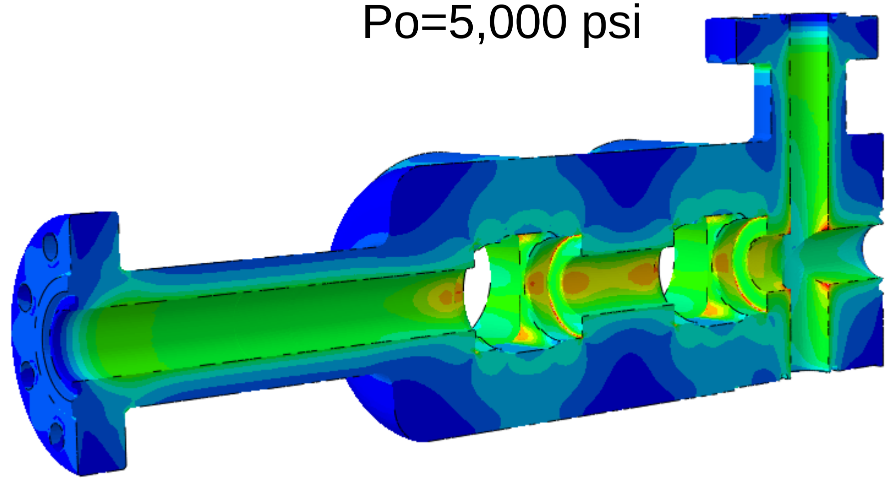
LC2:
Pi=20,000 psi
Po=5,000 psi

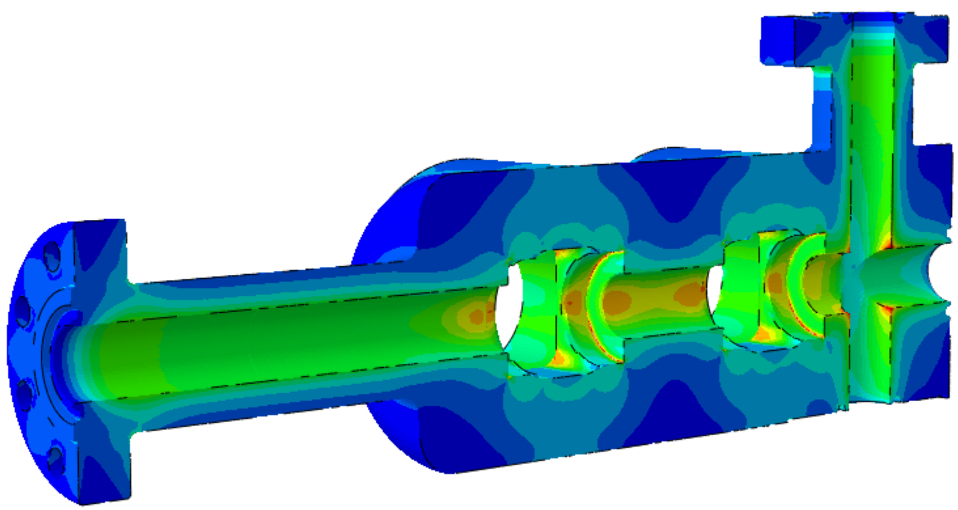
von Mises Stress Comparison

LC1:
Pi=15,000 psi
Po=0 psi



LC2:
Pi=20,000 psi
Po=5,000 psi





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Pi=18,000 psi
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von Mises Stress Comparison

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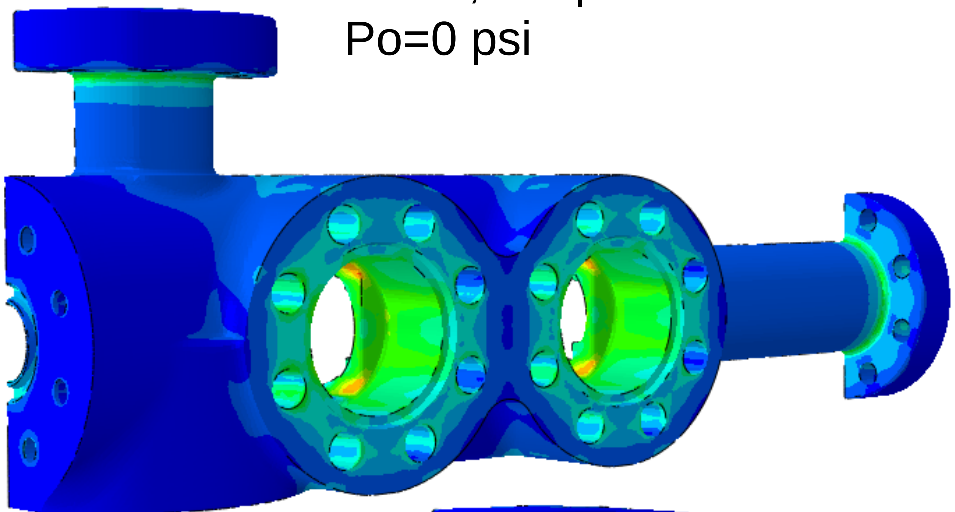

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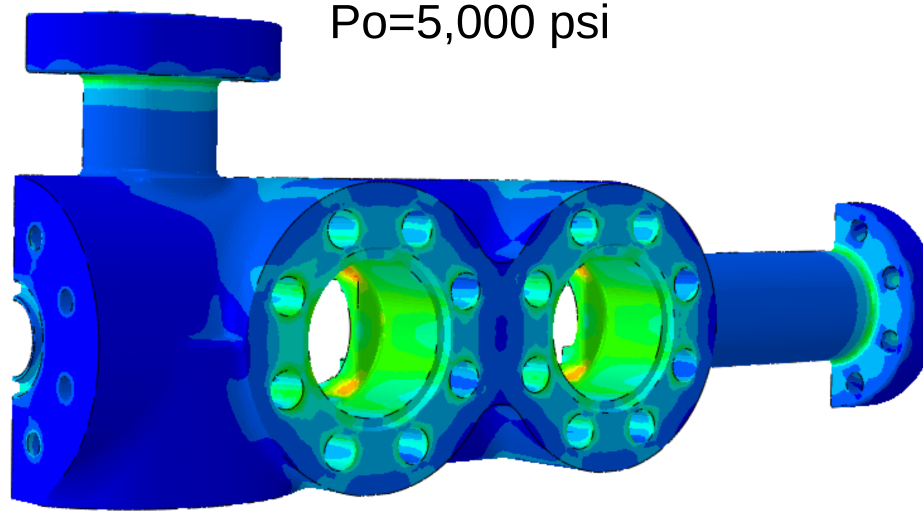
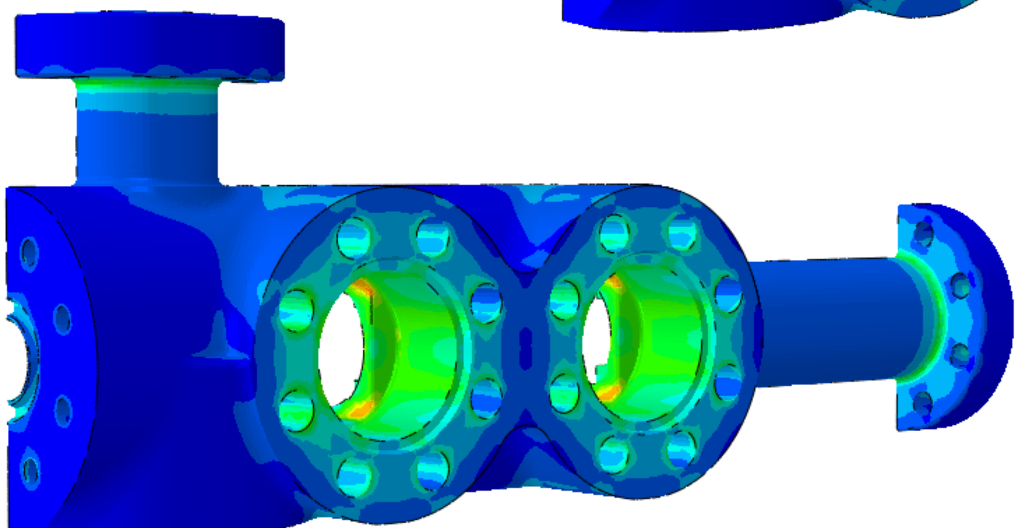
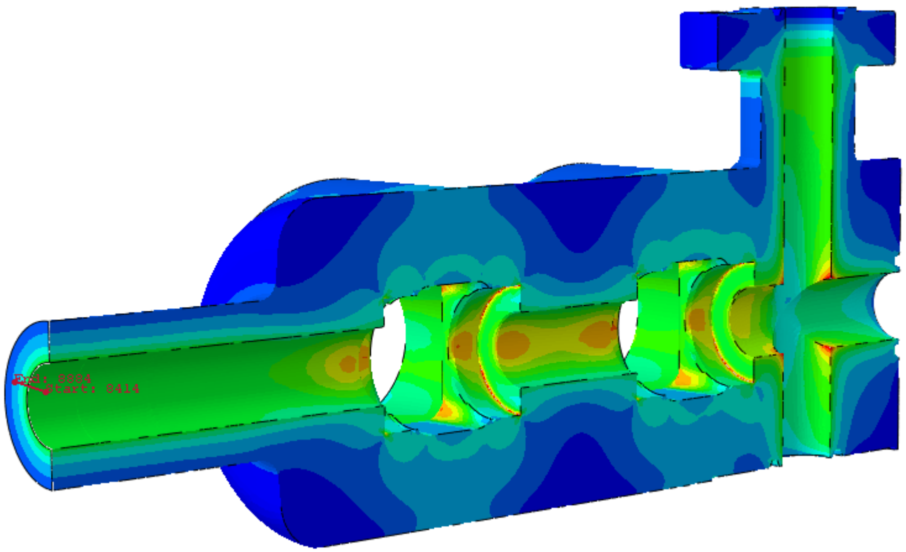




LC3:
Pi=18,000 psi
Po=3,000 psi

Stress Linearization



LC-1_CAE3_Oct10 - Notepad

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	Max. Prin.	Mid. Prin.	Min. Prin.	Tresca Stress	Mises Stress
Membrane (Average) Stress	15584.3	5358.47	-5106.81	20691.1	17919.4
Membrane plus Bending, Point 1	22452.1	5611.54	-12011.5	34463.6	29848.9
Membrane plus Bending, Point 2	8717.04	5106.51	1796.2	6920.84	5995.5
Peak Stress, Point 1	2991.42	-30.7043	-2913.3	5904.72	5114.11
Peak Stress, Point 2	1788.34	-18.1348	-1813.11	3601.46	3118.96

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	Max. Prin.	Mid. Prin.	Min. Prin.	Tresca Stress	Mises Stress
Membrane (Average) Stress	12583.7	2358.61	-8106.86	20690.5	17918.9
Membrane plus Bending, Point 1	19451.3	2611.03	-15011.6	34462.9	29848.3
Membrane plus Bending, Point 2	5716.6	2107.31	-1203.79	6920.4	5995.09
Peak Stress, Point 1	2991.36	-30.8123	-2913.21	5904.57	5113.98
Peak Stress, Point 2	1788.37	-18.0863	-1813.12	3601.49	3118.98

LC-2_CAE3_Oct10 - Notepad

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	Max. Prin.	Mid. Prin.	Min. Prin.	Tresca Stress	Mises Stress
Membrane (Average) Stress	10583.2	358.71	-10106.9	20690.1	17918.6
Membrane plus Bending, Point 1	17450.7	610.686	-17011.7	34462.4	29847.8
Membrane plus Bending, Point 2	3716.34	107.853	-3203.8	6920.14	5994.85
Peak Stress, Point 1	2991.34	-30.8797	-2913.16	5904.5	5113.92
Peak Stress, Point 2	1788.36	-18.0595	-1813.11	3601.47	3118.97

Stresses Comparison Results For All Nodes

Node #	LC1		LC2		% von Mises Difference	Node #	LC1		LC3		% von Mises Difference
	% von Mises Stress	% Maximum Principal Stress	% von Mises Stress	Maximum Principal Diff (psi)			% von Mises Stress	% Maximum Principal Stress	% von Mises Stress	Maximum Principal Diff (psi)	
Avg	19.98	15.72	20.02	-4889.01	0.81	Avg	19.98	15.72	20.00	-2936.83	0.38